Modern Food Packaging Technologies: Regulatory Aspects and Global Trends

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Welcome to the NPTEL online certification course on Modern Food Packaging Technologies, Regulatory Aspects and Global Trends. In the last lecture, we have discussed about blow mold and injection mold technologies and form fill sealing technologies. Now in this lecture, we will be discussing the thermoforming of the plastic materials. The thermoforming is a plastic manufacturing process that uses pressure or the force of a vacuum to stretch thermoplastic material over a mold to create a three dimensional shape part configuration or other form of plastic product. Cups, containers, lids, trays and clamshells are formed by thermoforming using thin sheets of thermoplastic while thicker sheets of thermoplastics are used to produce car doors and dash panels, refrigerator liners and plastic pallets.

The two processes used for thermoforming are vacuum forming and pressure forming which are used to stretch the heated thermoplastic over surface of the mold. Although the two processes are similar, they have unique properties that make them applicable to fit the needs of a projects design and must be chosen in accordance with the projects requirements. The forming phase of the thermoforming happens in a mold cavity when the plastic sheet is drawn by air or vacuum pressure. The mold cavity contains the shape of the single part, the mold tool sometimes referred to as tooling is a collection of mold cavities.

The steps of thermoforming are simple and straight forward which makes it suitable for high volume manufacturing of molded products due to its fast turnaround times. Thermoplastic sheets are continuously fed into the heating chamber and the formed into the desired shape. For the thermoforming of larger parts, the thicker thermoplastic sheets are fed individually. In some operations, an extrusion machine is placed upstream of the thermoforming machine. Certain setups are designed to produce multiple parts with each stroke of the press using molds with several cavities.

The thermoforming process takes a sheet of thermoplastic carefully heats it until it is sufficiently pliable, places it over a forming mold that forms it into a three dimensional shape and completes the process by trimming and finishing it into the desired shape of the product. It is a simple process that is quick, efficient, time saving and highly productive. Regardless of the simplicity of thermoforming, each step of the process has to be completed with precision and accuracy in order to produce quality parts and products. Any error can lead to deformed, damaged and useless sheets of plastic. There are three steps which are heating of plastic sheets, forming plastic sheets in mold cavities, trimming formed sheets.

The first is heating plastic sheets. The plastic sheets to be molded which has length and

width greater than the finished product is clamped into a holding device and transported into a heating equipment to raise it to the forming temperature. The sheet is heated by constant heating using panel and rods by exposing them to circulating hot air or using infrared heaters. The type of heating system is chosen depending on the material and the amount of necessary heat. The heating process is critical to the forming process since it creates the necessary pliability and flexibility.

Forming temperature vary depending on the type of thermoplastic being used. The application for the finished part and the forming technique. This is one of the most important operating parameter in thermoforming to meet certain quantity quality standards. Take note that the true forming temperature of a sheet is its core temperature not its surface temperature.

Hence, it is important to calculate heat transfer across the sheet. Now, the forming plastic sheet in mold cavities. The heated plastic sheets are removed from the heating equipment and transported to a temperature controlled and preheated mold tool. At this stage the plastic sheet takes the shape of the mold cavity which contains the desired form of the finished product. This stage gives the product its three dimensional characteristics that is length, width and height.

The mold tool may be positive or negative tool depending on its form. The positive tool, positive tool or the male mold is convex shaped the heated plastic sheet is positioned above the convex tool. The hummed surface or the convex surface will now give the plastic sheet its final shape. The exterior surface of a positive mold tool will give a shape of the inner surface of the part. This figure denotes that that this is the convex surface that is the male part of that and here there are plastic sheet is clamped between two clamps and which is heated either by infrared heating or by hot air or by heaters and then it is placed over that and then the vacuum is generated then it takes the shape of the mold.

Negative tool, the negative tool or female mold on the other hand is concave shaped the interior surface contour of the negative mold tool will give the shape of the outer surface of the part. After forming the plastic containing the new shape solidifies by cooling using air circulation or liquid cooling systems. The tool material used significantly affects the cooling cycle thus also affecting the quality of the parts. Trimming of form sheets. The sheet containing the formed parts goes through a trim station or 5 axis CNC router where a die, abrasive wheel or circular saw cuts the parts to separate them from the sheet web.

The trimmings are recycled and reprocessed to form other parts. This figure denotes the female or negative mold operation. The vacuum forming, the process of heating or shaping the plastic material using a vacuum is called vacuum forming. Vacuum forming is one of the oldest and cheapest methods for plastic molding and is widely used in everyday life. From smaller objects to huge industrial machinery, the vacuum forming process is being used at a large scale due to its low cost efficiency, speed of imitation, and ease of use for shaping a smaller objects mold.

Vacuum forming is a process in which a layer of plastic is placed on a mold and then the suction force is applied to shape the plastic according to the shape desired. The vacuum forming is also known as the simplest form of plastic thermo forming as only a mold is required and the plastic is placed over it. The vacuum forming as discussed earlier is the simplest of all forms. Still now advanced technology is being introduced such as heat, hydraulic and pneumatic controls to produce more precise and desired products at a reasonable production speed. Many products are made from vacuum forming such as bath and shower trays, vehicle parts, refrigerator liners, plastic storage boxes etc.

Here it is depicted in the picture which also resembles with the negative tool which we have discussed earlier the simply the plastic sheet is heated and it is kept over a tool which forms the mold and then vacuum is applied and due to suction forces that molten sheet it takes the shape of the mold and after cooling it is then ejected. Now the pressure forming, similar to the vacuum forming method air pressure is utilized together with the vacuum applied under the cavity to push the plastic sheet. The added air pressure creates greater detail for example, textured surface undercuts and sharp corners on the finished product that is not easily created by vacuum forming. Making this method suitable for products with complex designs pressure forming is done with the help of two molds. The sheet is placed within one mold and then pressed by placing the other mold on it rather than using suction from the vacuum pump.

This process enables precise and aesthetically good looking molds such as appliances, casing etcetera. Furthermore, pressure forming is very suitable for manufacturing the plastic parts that are needed to be shaped evenly and that go deeper into a mold. The pressure forming is presented in the adjacent figure here also the same thing the plastic sheet is clamped into two clamps and then it is heated and then either vacuum or the pressure both can be applied to give the shape of the heated thermoplastic sheets. Now, the matched mold forming, matched mold forming is where the heated thermoplastic sheet is shaped by a male and female mold which can be made of metal plaster, wood or epoxy resin. When the halves of the mold are closed distort the sheet of thermoplastic to take the shape of the halves of the mold.

As the mold closes excess air is removed to form a tight seal by the application of a vacuum. The walls from matched mold forming are more uniform and adhere closely to design tolerances. The process allows for exceptional dimensional control and offers the ability to create intricate and complex shapes. The matched mold forming is presented in this figure where the molded mass is kept in the two halves one is male part and another is the female part and then it is pressed and then after cooling the air is sucked out with the help of vacuum and then it is mold is opened to take out the material. The twin sheet forming, the twin sheet forming involves two plastic sheets simultaneously heated and formed using two mold tools for each half of the part.

The mold tools are then precisely pressed together on the edges to connect the two halves. This method is used in producing double walled three dimensional parts and hollow tubes such as air ducts, pipes and tanks. The materials used in thermo forming, the thermoplastics are the raw material of the thermo forming process. Thermoplastics

are a broad class of polymers that can be heated to a certain elevated temperature and recasted reversibly without altering their chemical properties and associated phase changes. It can survive multiple cycles of heating and cooling.

Given this nature thermoplastics can be reprocessed and are recyclable material. Similarly thermoplastics can be thermo formed. Thermosetting and elastomeric plastics in contrast cannot be reshaped once the polymeric chain have been cross linked. A forming temperature is any point located above the glass transition temperature and below its melting temperature. When the temperature of a thermoplastic is increased gradually the intermolecular forces in the polymeric chains are also weakened gradually until it reaches the glass transition temperature.

Above the glass transition temperature the once rigid and brittle solid is turned into a soft and pliable rubber like material. The thermoplastics are grouped into either amorphous or semi crystalline structures. Amorphous thermoplastics these materials have a random molecular structure and have a wide range of softening temperatures. Some advantages of amorphous thermoplastics they have good dimensional stability, higher impact resistance, bond well with adhesive and are easier to transform than semi crystalline thermoplastics. However they have poor fatigue resistance and are prone to stress cracking.

Some of the amorphous thermoplastics are polycarbonate, acrylic and high impact polystyrene. Semi crystalline thermoplastics these exhibit an organized lattice at a temperature lower than its melting point. This type is known for its excellent wear and bearing resistance making it ideal for structural applications and durable plastic parts. This type is also known for its better chemical resistance and insulation properties. Some disadvantages of this type they are difficult to thermoform and are bond with other formed parts and they only have average impact resistance.

Examples of semi crystalline thermoplastics are polyethylene, polypropylene and nylon. Benefits of thermoforming low cost, large parts are normally used in larger assemblies and products. Although they can be produced using other forming methods thermoforming is capable of producing large parts of half the cost and the less time than any other plastic production method. From car door panels and instruments panel to tail lights and consoles thermoforming can complete this job quicker, easier and at less expense. The durability a key to modern production is the ability of products to last and endure the harsh and endure the harsh and rugged treatment they receive.

One of the main factors in consumer satisfaction is how long a product will last and is a main marketing point. The next benefit of thermoforming is tooling costs. Thermoforms molds are easily engineered using 3D printing or computer aided design. They are made from silicon, fiber glass or other materials and do not require grinding, machining or other forms of tooling. The creation of a metal mold is expensive, time consuming and labor intensive.

It requires highly experienced professionals with the proper skills. The another

important is development. Thermoforming uses tools made from wood or epoxy. The tools for thermoforming can be used to create an assortment of finished parts that represent the initial design. Prototypes are formed from the same materials as those used for the final product allowing for the identification of design flaws or issues before approving production tooling.

Design the thermoforming has very few limitations in regard to designs regardless of the intricacies details or size of a parts design. This aspect of thermoforming is one of the main reasons for its popularity especially in automobile design where the weight of components is a major concern. There are certain disadvantages also associated with thermoforming which are individual part cost can be higher than injection molding. Molded in components such as screws, fasteners and clips cannot be included. With any geometry the front side will be the same as the back side.

Part thickness can be an issue and may not be even across all surface of the part. All forms of thermoforming produce a great deal of waste which can be recycled. Now the compression molding. compression molding is a method of molding in which the molding material generally preheated is first placed in an open heated mold cavity. The mold is closed with a top force or plug member pressure is applied to force the material into contact with all mold areas.

While heat and pressure are maintained until the molding material has cured. This process is known as compression molding method and in case of rubber it is also known as vulcanization. The process employs thermosetting resins in a partially cured stage either in the form of granules, putty like masses or preforms. Compression molding is a high volume high pressure method suitable for molding complex high strength fiberglass reinforcements. And advanced composite thermoplastics can also be compression molded with unidirectional tapes, woven fabrics, randomly oriented fiber mat or chopped stands.

The advantage of compression molding is its ability to mold large fairly intricate parts. One of the lowest cost molding methods compared with other methods such as transfer molding and injection molding. Moreover it wastes relatively little material giving it an advantage when working with expensive compounds. However compression molding often provides poor product consistency and difficulty in controlling flashing and it is not suitable for some types of parts. Fewer knit lines are produced and a smaller amount of fiber length degradation is noticeable when compared to injection molding.

Compression molding is also suitable for ultra large basic shape production in sizes beyond the capacity of extrusion techniques. Materials that are typically manufactured through compression molding include polyester fiberglass resin system, Tarlon, Vespel, polypropylene sulphide and many grades of PEEK. In compression molding there are six important considerations that an engineer should bear in mind. The determining the proper amount of material, determining the minimum amount of energy required to heat the material, determining the minimum time required to heat the material, determining the appropriate heating technique, predicting the required force to ensure that short

attains the proper shape, designing the mold and rapid cooling after the material has been compressed into the mold. Thank you very much.